

A Scheme of Colour Standards.

THE confusion which has long prevailed, and does not promise any immediate disappearance, in the use of colour names, is an inevitable consequence of the absence of any definite standards of colour. In music and form we have well-established and very satisfactory terms to describe definite sense perceptions, and it would be difficult to conceive how we could dispense with them; but for colour perceptions we have neither any well-defined concepts for those terms which have become well established, nor any definite and well-arranged system of colour terms for common use. Those terms which have acquired a somewhat definite significance are nevertheless used for a very wide range of variation. Vermilion and ultramarine, terms which have been used by many of our best authorities on colour, for want of anything better, as a basis for comparison and analysis, are nevertheless used for very variable concepts. The difference between a Chinese and a German vermilion in pigments is very noticeable. A Winsor and Newton "chrome yellow" and a German "chrome yellow" differ by more than twenty-five per cent. of yellow. Among several samples of blue pigments a still greater variation is generally found. When this is true of such terms, what shall we expect will be the case with that very much larger group of terms whose meaning has never reached any considerable degree of accuracy, as olive, citrine, russet, &c., or that still more vague but innumerable class of terms in vogue in popular usage, like "crushed strawberry," "baby blue," "ashes of roses," "peacock blue," "hussar blue," and a host of others still more vague and transitory?

Naturalists have been at very great inconvenience because of the lack of any agreement in the use of colour terms for botanical, entomological, and ornithological descriptions. Our greatest American authority in descriptive botany is sometimes confusing in his description of flowers because of this lack of any standard terms with admitted significance. Zoologists, too, have sought in vain for some basis of agreement, and the futile attempts to establish some such basis of agreement are familiar to every ornithologist.

In applied science and the arts the inconvenience has, if possible, been still greater, inasmuch as the number of persons interested is larger. And this inconvenience is steadily increasing as the revelations of chemistry disclose hues more and more brilliant, for which new names are as constantly coined. With the rapid advance of the art of dyeing the necessity of some system of colour nomenclature becomes more and more imperative.

The valuable research of Prof. Rood has contributed greatly to our knowledge of colour, and that in a time when much less was known on the subject than now. The later contributions of Abney and Church in England have also given valuable additions to the science of colour. The able works of Chevreul, Koenig, and Von Bezold are also important contributions to the subject. Above all, the masterly works of Helmholtz, Hering, Kühne, and Carpentier are most valuable contributions upon this subject.

But while these have given the greatest help to our understanding of the nature and relations of colour, none of them has given any solution to the problems just now hinted at. No system of colour nomenclature has been offered, nor any set of colour standards proposed.

It was in view of these difficulties that the writer proposed, about twelve years since, while connected with the Springfield, Massachusetts, High School, as teacher of physics, botany, and zoology, that a series of colour standards, based on the hues of the solar spectrum, and selected by a consensus of colour experts, should be adopted as a foundation of all our colour work, and especially that its use in all educational work be made the means of establishing a better and more accurate knowledge of colour. This proposition was received with favour from the first by those to whom it was mentioned, and an attempt was soon made to put the scheme into material form; but the difficulties which lay in the way of producing any pigmentary hues which could in any adequate degree represent the hues of the solar spectrum were so great, that very little progress was made for several years.

The wave theory of light long ago established the fact that vibrations of an almost infinite variety of wave-length in the luminiferous ether impinge upon the human retina and produce the effect which we call white light. From these we may select any wave-length we please, and giving it a name, have a colour as accurately fixed as any musical note or geometrical form. The desirability of such a definiteness in the terms which describe

colour, all will immediately recognise. It is not necessary that a large number of thus accurately fixed colours should be made the basis of colour nomenclature, for then the eye could not distinguish between the colours selected. Every eye can, however, unless it be colour-blind, distinguish six well-marked colours in the solar spectrum, for which there are well-recognised names. The theory of three primary colours from which all the other hues of the spectrum are derived is no longer possible with the present knowledge of the laws of light, and the always questionable indigo of the rainbow is no longer recognised as one of the distinct spectrum colours. As a matter of practical convenience we may select any number of colours which is found to be desirable for standards if only they are accurately defined. This has been done for the six commonly recognised spectrum colours, red, orange, yellow, green, blue, and violet.

To obtain the agreement of six or eight persons well skilled in the use of colours as to exactly what portion of a projected spectrum of eight or ten feet long should be selected for each standard was a much less difficult task than would first have been supposed. It was found that very great unanimity of judgment prevailed when the comparison was made. The portion of the spectrum having been selected for each colour, two other things yet remained to be done. These were very important factors of the proposed scheme.

First of all the exact location of the area must be determined by careful measurement of the wave-length of its centre. This would make it possible to ascertain or relocate the standard in any part of the world without any material representation of the colour designated; in other words, this makes possible the use of the designated colour as one of a series of universal standards. To render any set of standards of most permanent and wide value, it is desirable that it be adopted by somebody whose authority will be generally recognised. In the case of standards of measurement, the Government establishes standards in the interests of commerce and equity. In most other cases some learned society adopts the standard, and thus gives it the benefit of its own authority. The American Metrological Society has appointed a committee with instructions to report a recommendation for the establishment of six standard colours. The endorsement of such a society would go far toward the establishment of any scheme of colour nomenclature if the scheme be a practical one. Without the element of practicability no authority could make such a scheme of any value.

After several years of careful study of the practical problems involved, especially the relations of the colour standards to one another, it was found that to select any particular pigment as one of the standards, and make the scheme adapt itself to this as a standard, was not only unscientific but unpracticable. The standards if selected with a view to practical or artistic purposes, and most of all with the hope of making the scheme of educational value, must bear a relation to one another not unlike those of the musical scale. It must be possible at least that the union of these standards should produce the intermediate hues of the solar spectrum in colour if not in purity. After much care six standards were selected and at once put to practical use. This was as early as 1884. The exact measurements of the wave-lengths of these standards were published in *Science* for June 9, 1893. The values there given were as follows: Red 6587, orange 6085, yellow 5793, green 5164, blue 4695, violet 4210, in ten-millionths of a millimetre.

These measurements are for the centre of an area of the solar spectrum represented by fifty of the same units. A measurement differing from either of these by twenty or twenty-five would hardly vary to a degree to be perceptible to the trained eye, much less to the ordinary eye. There is, however, a very great variation in different parts of the spectrum. In the orange, yellow, and green, where the change is rather rapid, a small difference is very readily perceived, while in the red as well as in the blue and violet the same difference would be scarcely noticeable.

To Mr. Milton Bradley, of Springfield, Massachusetts, is due great credit for first undertaking to put this idea of spectrum standards into practical working material. When the idea was first proposed he was largely engaged in the manufacture of coloured papers for educational purposes, and he at once undertook to reproduce the spectrum colours in his educational papers. The task proved no easy one, notwithstanding the great advance which the discovery of the aniline dyes had made in the production of brilliant colours. It was only with the utmost persistency that Mr. Bradley was able to accomplish the task which he had voluntarily undertaken. After long and repeated experi-

ments he succeeded in getting coloured papers which are very good reproductions of the hues of the solar spectrum. These papers have now been used for several years very extensively in kindergarten and primary school work, and they are an important means toward the education of a new generation of students to a true conception of colour, a more careful use of colour terms, and a sharper discernment of colour perceptions.

At a meeting of the Society of American Naturalists, held in Boston, December 31, 1890, I read a paper in which was given a more elaborate carrying out of the scheme which I had previously proposed.

In order that any fixed scheme of colour nomenclature may be of some practical value it must, of course, be readily understood by people of only ordinary intelligence, and must be complete enough to meet the ordinary wants of everyday life. There must be something that is so completely fixed as to be perfectly trustworthy for present and future needs.

In the solar spectrum we have an invariable source from which to derive our spectrum standards, and upon these the whole scheme is to be based.

Since, however, the six spectrum standards do not give a very extensive *répertoire* for common use, to say nothing of the needs of the more artistic, it was proposed to introduce between each two spectrum standards two intermediate hues to be formed by the union of the two spectrum standards in definite proportions. Thus between orange and red would be introduced an orange-red and a red orange. In the former red would predominate, while in the latter orange would be more prominent. Inasmuch as these hues are only intended to be combinations of the spectrum standards, it is not necessary, or even perhaps desirable, that these hues be absolutely fixed. If, however, this is desirable in any particular case, it can be accomplished in a manner which will be indicated subsequently. In addition to the two hues introduced between each two standards it is also necessary to use a violet-red and a red-violet (or two purples, a reddish purple and a violet purple) to represent the actual combinations which occur in nature.

It is also very desirable that the standards be produced in some material form in order that it be of any practical value. The task of reproducing the brilliant hues of the solar spectrum in pigmentary material or in glass is much more difficult than one not acquainted with the matter would suspect. It would not be difficult to select well-known pigments, and then determine the wave-length which most nearly corresponds to the hue of the pigment; but any number of such selections would not form a symmetrical series of colour standards. The colours for such a scheme being selected and their wave-length determined, the other and more difficult problem is that of finding some combination of pigment which will reproduce it. This task of reproducing the spectrum hues was a very difficult one. It is impossible to reproduce some of the spectrum colours with the ordinary pigments either in hue or in quality.

Almost at the very outset of this work in colour it was found that it would be necessary to depend upon the somewhat fugitive aniline colours for some of the standards as the only colour material which would approach the spectrum hues in brilliancy. The difficulty of keeping the standards up to tone, so to say, while using somewhat changeable material, is a serious inconvenience but not an insuperable barrier. With the solar spectrum recognised as the source to which we must always go to correct our standards, the great difficulties of colour-study are met. The most desirable thing now to be accomplished is the discovery of some permanent colour material in which to reproduce the spectrum standards. Some convenient form of tablet would then be produced which could be supplied to all who are willing to provide themselves with it, and to these all questions of colour would be referred. The standards thus established, the intermediate spectrum hues are determined by them.

Now, by the use of the Maxwell discs in the standard colours described above, we may fix upon definite proportions of each which we will use for any other hue. If, for example, we desire to introduce between red and orange two hues, we must first of all know something of the relative effect of the two colours, and combine them in inverse proportion to what we are accustomed to call the value of the colours. The colour which has the lowest value will require to be used in larger proportion than the other. In this case we may take a red and an orange disc and put them together in the manner above described. For convenience of measurement, a disc just a little larger than the coloured discs,

with the margin graduated into one hundred degrees, is placed behind the coloured discs, and the sectors adjusted as desired. As the red has the lowest value, more of the red disc must be exposed in order to produce an effect equal to that produced by the orange. If it is desired, therefore, to introduce two hues between red and orange, we must still more increase the proportion of red in the combination which we wish to be most like the red. For our orange-red we may use 70 per cent. of red and 30 per cent. of orange, and for our red-orange 59 per cent. of red and 41 per cent. of orange. By making a scale of values for the six standard hues, we may combine them in the manner we have just illustrated and form two hues between each of the standards, and two more by combining red and violet. These twelve hues, with the six standards, give a sufficiently large variety of hues for practical purposes.

For purposes of colour education, however, it must be borne in mind that pure spectrum colours are not often seen either in nature or art. And while it is very important that the student should be taught the spectrum colours at the outset of his education in order to establish some accurate knowledge, derived from the only source of accuracy, the solar spectrum, it is also important that he should become familiar with the effect produced by the mingling of these spectrum hues with the light reflected from other objects, as well as the effect of shadow upon the colours themselves. The mingling of white light with any colour produces a tint of that colour. The tints are what we most often see in all except the most brilliant colours of flowers, not generally of the standards but the intermediate hues. On the other hand, when a coloured object is seen in shadow, or, what is more common, when the coloured surface is so irregular as to reflect here colour and there give no reflection, the effect is to produce a shade of the colour. In foliage the prevalence of shades is the rule, whether we consider the individual leaves or the masses of foliage. A knowledge of these effects is best acquired by the use of a very few tints and shades of each hue. Any convenient number of tints and shades can of course be designated, but a few will serve all the purposes of ordinary educational work. In their educational papers the Milton Bradley Company use the six spectrum standards, twelve intermediate hues, including the combinations of red and violet, two tints and two shades of each of the pure colours, thus giving in all a range of ninety different modifications of colour. With these are used black and white, together with a variety of greys. The facility with which young children learn to distinguish and designate colour is really quite surprising.

But a still larger proportion of the colour effects of nature and art than those produced from either tints or shades are the result of both light and shadow combined with colour. This effect has been well enough described by the term "broken colour." In order to acquire familiarity with this effect, it is desirable to use a series of broken standards, if not also of the twelve intermediate hues. These should be made, as should also the tints and shades, by using proportions which take into account the value of the colours, and, above all, the proportions of white and black used should be such as to avoid destroying the characteristic effect of the colours. Each of these broken standards may have its tints and shades like the standards themselves by increasing the amount of white or black which is combined with the colour.

But perhaps the most interesting point in connection with the introduction of definite colour standards will be the possibility of talking about colour in a definite language. Without such standards this has been impossible. By the use of the Maxwell discs made in the standard colours we may easily determine the composition of any colour. This is a great convenience in the description of colours, for it renders it possible when it is necessary to give an exact meaning to any colour term. Only with standards which can be accurately fixed is this possible. The use of such terms as vermilion, emerald green, ultramarine, chrome yellow, and similar terms as a basis of colour analysis is exceedingly impracticable, since even these terms, although by far the most definite terms in common use, are quite too variable to give results which can be of any real value. For the sake of convenience, the first letter of each colour is used as the symbol of the colour in all formulae in which the analysis or composition of colour is expressed. N is used for black, to avoid the repetition of B which is used for blue.

The following formulae will illustrate the practical application of the idea and the value of the spectrum standards in determining the composition of colours. They will also be of interest as

showing the simplicity of the proposed nomenclature and method of expressing the results of analysis.

The first series illustrates the variability of the pigments used by artists. These analyses are made by Mr. Bradley.

A Winsor and Newton "cinnabar green" gives—Y 14, G 11½, N 74½.

A German pigment of the same name gives—Y 12½, G 11, W 2, N 74½.

A Winsor and Newton "light red" gives—O 24, N 76.

A German pigment of the same name gives—O 18, N 82.

A Winsor and Newton "chrome yellow" gives—O 29, Y 71.

A German pigment of the same name gives—O 35, Y 45, N 20.

A Chinese vermilion gives—R 77, O 23.

A yellow ochre gives—O 24, Y 24, N 52.

An Indian red gives—R 7½, O 17½, N 75.

An emerald green gives—G 63, B 14½, N 22½.

One called "chrome green" No. 2 gives—G 16½, Y 55, N 78½.

The following series illustrates the significance of the terms used in describing the colours of dress goods. A very wide range of tints and shades of the colour which is the basis of each term will often be designated by the same name.

A sample of goods called "écru" is—O 11, Y 13, W 18, N 58.

Another sample marked "raisin" gives—R 18, V 14, W 5, N 63.

A sample called "ashes of roses" gives—R 8, V 4, W 14, N 74.

The popular colour called "eminence" gives—R 14, V 19, N 67.

Another popular colour called "emerald" is—G 21, B 3, N 76.

A sample called "crushed strawberry" gives—R 55, O 5, W 27, N 11.

One having the poetic name "absinthe" gives—Y 35, G 45½, N 19½.

Another called "Marion" gives—R 4, O 3, N 93.

A specimen of "hussar blue" gives this—G 4, B 15, N 81.

A sample called "oasis" gives the formula—Y 7, G 10½, W 8½, N 74.

Another called "dove colour" gives—B 9, W 9, N 82.

Still another, called "prairie," gives—Y 10½, G 14½, N 75.

A colour called "Styx" has this formula—R 9½, W 21½, N 69.

A sample of "peacock blue" gives this—G 4½, B 8½, N 87.

A brown, called "vidette," gives this—O 4½, Y 3, N 92½.

A sample of "navy blue" gives—B 6, N 94.

Another of "Turkey red" gives—R 98, O 2.

A rather dark "plum colour" gives—R 3, V 4, N 93.

A few analyses of flowers will be of interest to others beside the botanist.

The Fringed Polygala (*P. paucifolia*) is—R 48, V 52.

The Wistaria (*W. frutescens*) gives—for the wings R 11, V 89; and for the standard R 9, V 79, W 12.

The Flowering Quince (*Cydonia japonica*) gives—R 95, V 2, W 3.

The wild Cranesbill (*Geranium maculatum*) gives—R 28, V 66, W 6.

The Fuchsia (*F. viridissima*) is pure spectrum yellow.

The variations of foliage are worthy of note, and a few examples of analyses of the colour of various leaves will perhaps be of interest.

It is possible that some knowledge of these variations on the part of more of our artists might save us some of the abominable greens which so often appear in paintings, otherwise of an excellent grade.

Leaves of the White Oak give—Y 7½, G 11½, N 81.

" Apple are—Y 5, G 13, W 2, N 80.

" Copper Beech give—R 17, V 2, N 81.

" Hemlock Spruce—Y 2, G 9, N 89.

" White Pine give—Y 2½, G 11, N 86½.

" White Birch give—Y 5½, G 11½, W 1, N 82.

" Hornbeam—Y 5½, G 12½, N 82.

" Shagbark Hickory—Y 4½, G 9½, N 86.

With discs made in the spectrum standards colour can thus be analysed and the results, expressed as in the examples just given, can be utilised by any number of persons to determine the particular colour about which a statement is made. As these discs are not expensive, and the means of rotating them very

simple, they ought to come into very general use. It is only necessary that they be rotated with sufficient rapidity to cause the colours to blend smoothly. For the purposes of studying the harmony and contrast of colour it is desirable to have discs of several sizes, so that two or three combinations of colour may be made upon the colour-wheel at the same time and compared.

Among the practical applications of such a scheme of spectrum standards as that outlined in the preceding paragraphs, some of the most obvious are the only ones which need be mentioned in this connection.

A firm dealing in large quantities of coloured material desires to order a stock in a particular colour which they have not used, and of which they have therefore no samples. By the old method they must find something as nearly like what is desired as possible, and then dictate as best they can just what variations are to be made. Now they can produce the colour with the discs and send the formula only to their manufacturer, who also has a set of the discs, and he "sets up the colour" and then reproduces it in the material desired. The gain is great in several ways. In the first place it saves the dealer much costly experiment to determine just what he really wants. Again, if he is in doubt as to just what a customer wants, he takes him to his colour wheel and ascertains what the desired colour is, and then communicates it to the manufacturer. The architect may spend much time and effort to have his carefully-planned and beautiful villa painted in colours which will be at once in keeping with the style of architecture and the surroundings of the building; but unless he confine himself to colours ready prepared and of certain composition, he is liable to extreme disappointment. A similar use of the colour wheel with standard discs would greatly reduce his difficulties. The artist who accustoms himself to the analysis of colour effects will soon find that he is able to write estimated formulæ which will be of service to him in the subsequent composition of his observations. Above all, the child who is thoroughly educated in any scheme of colours which has a definite basis, and consists of a well-selected series of standards, is starting with a most valuable groundwork for future knowledge and practice. Hence it is that the introduction of systematic colour work into the kindergarten and primary school has so much of encouragement to those who desire a reformation in the use of the terms which describe colour perceptions. Why may we not hope for the time when a system of colour terms with something of the same definiteness as those used in music shall be in common use? Surely there is need of this, and the time is not far distant when this need will so assert itself as to bring about a revolution in our methods of colour education.

Malden, Mass., U.S.A.

J. H. PILLSBURY.

Globular Lightning.

ON June 21, about 6 p.m., Dr. Wallis, Mr. Taylor and myself were in our drawing-room on the ground floor, taking shelter from a passing storm; they were seated, and I stood five paces from them. The doors were all closed against the storm, and I went out and, for cool air, opened one. On returning, I saw a globular light, about the size of the full moon, in the air between Wallis and Taylor, and almost instantly I heard in the room a terrific clap of thunder like a cannon. I suffered afterwards from acute pain down the left side of my face. Taylor, who had an iron-headed golf stick in his hand, felt a twinge up his right arm, and a sensation as of singing in his hair. Wallis felt nothing at all. We all experienced a sulphurous smell. In the adjoining room, leaning against one corner, were two Martini-Henry rifles in leather cases. One was untouched. The stock of the other was almost shattered, splinters lying about the room. The leather covering of the splintered rifle was torn, but the metal part of the rifle quite unhurt. At the point of the wall where the muzzle of the shattered rifle touched the wall, there was a hole 5 × 2½ and 1½ to 2 inches deep. The wall is of mud and plaster. In the room above were two holes in one wall; that is, the wall above that in which the hole appeared below. These holes were smaller than the one below. Just below the two holes stood a wooden case, iron-bound, and at its foot the matting was torn up, but the floor and the case were untouched. In the second room above, that is, the room over that in which I had seen the globular lightning, the wall near the ceiling was cracked for six or eight feet. This was all the damage done that we could find.

G. M. RYAN.

Karachi, July 18.

[The above letter was received from Mr. F. C. Constable, who saw the damage described.—ED. NATURE.]